Today's Topics

- The Problem
- Motivation
- MAUI
- Evaluation
- Summary

MAUI: Making Smartphones Last Longer With Code Offload

Slides based on a paper by:

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The Problem

- ❑ Cloud services are also ubiquitous
- ❑ Possess high computation capabilities
- ❑ Not limited by battery!
- ❑ Idea: mobile computation offloading to the cloud!

The Problem

- ❑ Mobile devices are ubiquitous
- ❑ Wider range of applications
- ❑ Mobile Computation gets more intense
- ❑ Battery fails to keep up...

Motivation

❑ Three questions quantify the need for remote offloading:

1. How Severe is the Energy Problem in Today's Mobile Devices?

- Synthetic benchmark (bulk fetching+display) drained battery after 1.5 hours
- Synthetic, yet realistic scenario (Video streaming)

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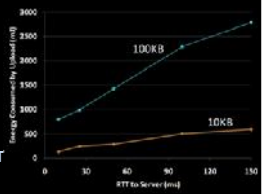
Motivation

❑ Three questions quantify the need for remote offloading:

3. How Sensitive is the energy consumed to the Wi-Fi RTT?

- 10/100KB offloading on Wi-Fi
- Near linear energy growth w.r.t. RTT
- Cloud should strive to minimize offloading RTT
- Energy saving is significant for nearby servers (RTT~10ms)

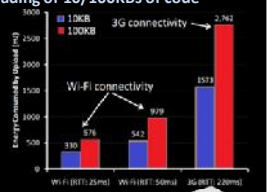


Motivation

❑ Three questions quantify the need for remote offloading:

2. How Energy Efficient is 3G for Code offloading?

- Researchers tested the uploading and downloading of 10/100KBs of code
- Energy(3G) is roughly 5x Energy(Wi-Fi)
- Battery drained after 2 hours of extensive use
- 3G might be impractical to use



MAUI

❑ Main Challenges:

- **Partitioning** - what is the granularity of the code that is offloaded?
- **Amortizing costs** – what is the minimal "state" for offloading?
- **Detection** - how to detect offload candidates "on-the-fly"?
- **Programmability** - do not over-burden the programmer

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MAUI

❑ The MAUI programming model:

- Methods are identified by attributes, server has matching messaging interface

```
// original interface
public interface IEnemy {
[Remoteable] bool SelectEnemy(int x, int y);
[Remoteable] void ShowHistory();
void UpdateGUI(); }

// remote service interface
public interface IEnemyServer {
MAUIMessage <AppState,bool> SelectEnemy(int x, int y);
MAUIMessage <AppState,MauiVoid> ShowHistory();
}
```

MAUI

❑ The MAUI programming model:

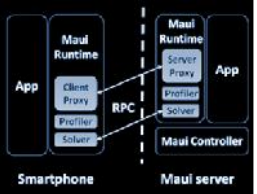
- C# applications containing "**remotable**" methods (marked by the programmer)
- Methods that do not implement UI
- Methods that do not interact with mobile device's IO devices (GPS etc.)
- Methods must be able to be re-executed (i.e. without irreversible side-effects)

MAUI

- The MAUI profiler
- Instruments methods to predict offload profitability,depending on:
  - The smartphone's energy consumption
  - Each method's characteristics (e.g. run-time and resources needed)
  - Network characteristics (RTT, BW latency, and packet loss rate)
- **Problem I**: serializing entire state is time-consuming
- **Problem II**: sending entire state wastes a lot of bandwidth
- **Heuristic Solution:** app-state delta calculation

MAUI

- The MAUI architecture:
  - **Proxy -** handles control + data transfers
  - **Profiler -** instruments the program
  - **Solver –** ILP solver (elaborated later)
  - **MAUI coordinator –** handles incoming requests, creates a partitioned application



- both device and server hold copies of the application (using CLR)
- Currently no support for multi-threaded applications ☹

MAUI

- The MAUI solver: attempts to solve the offload decision problem
  - Reaching the optimal solution requires a global view of the program
  - Formal problem definition: G(V,E) v= call stack method e=(u,v)→ u invokes v

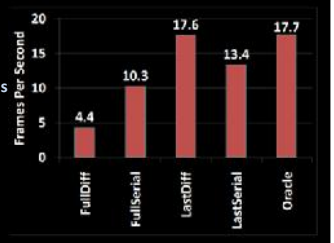
$$\text{maximize} \quad \underbrace{\text{Total offloaded energy}} - \underbrace{\text{Total energy of state transmission}}$$

$$\text{such that:} \quad \underbrace{\text{The time that takes to run both remotable and local methods}} + \underbrace{\text{The time taken by state transmission}} \leq L$$

$$\text{and} \quad \underbrace{\text{we're not offloading non-remotable methods}}$$

MAUI

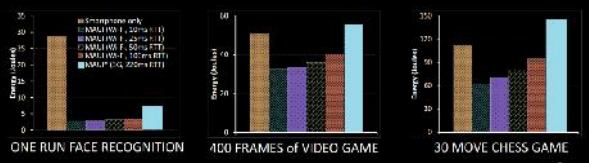
- The MAUI profiler
- Profiling policies
  - FullDiff – serialize and calculate deltas on every call
  - FullSerial – serialize on every call
  - LastDiff – serialize on first call only, calculate deltas for each call
  - LastSerial – serialize first call only
  - Oracle – knows exactly which methods to offload without calculation



Evaluation

❑ Methodology:

- 3 micro-benchmarks are evaluated (Face recognition, chess moves, video)
- 6 configurations: smartphone only, MAUI + 4 WiFi RTTs, MAUI* + 3G



ONE RUN FACE RECOGNITION | 400 FRAMES of VIDEO GAME | 30 MOVE CHESS GAME

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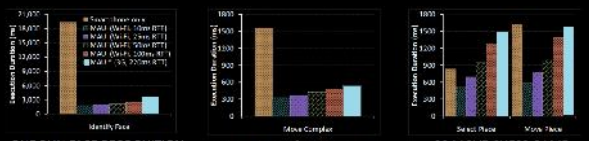

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Summary

- ❑ Combines two approaches:
  - Fine-grained partitioning (offload strategies are defined by the programmer)
  - Process and VM migration (limited choice for offloading, all done by the OS)
- ❑ Use of CLR: same copy of the application on the device and server
  - Provides architecture-independent execution (translation overhead?)
  - Idea: maybe MAUI server should run a VM simulating mobile device?
- ❑ Might provide benefits beyond energy savings
  - Can offloading improve performance?
  - Applications that could not run on mobile devices run on the cloud

Summary

- ❑ Conservative approach: relying on entire objects as AppState
  - WIP: static analysis tool check which vars are referenced by remotable methods
- ❑ In the MAUI solver section they only formulate the problem…
  - How does it really solve the problem? Does it really solve an ILP?
- ❑ Tested on three micro-benchmarks
  - What about other applications?
  - How much of the presented gain came from programming effort?
- ❑ Does the fact that 3G is wasteful make MAUI impractical?

Summary

- ❑ Timeliness!= Performance

Summary